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Study of Earthquake Disaster Population Risk Based on GIS

A Case Study of Wenchuan Earthquake Region

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Abstract

For the earthquake disaster frequently happened in china, it is necessary to do some research about risk analysis of earthquake. The paper analyzed major factors of earthquake disaster firstly, established earthquake disaster risk assessment model with data of earthquake disaster between 1966 to 2010 and determinated the value of three factors quantitatively. Finally, taking Wenchuan earthquake region as an example, used the spatial analyst function of ArcMap system, analyzed the risk of population in earthquake disaster and created the population risk distribution map with a division of population high risk areas.

Keywords：Geographic information system;earthquake disaster; population hazard; population risk

1. Introduction

China is one of the most serious damage countries suffered by earthquake disaster in the world, the earthquake is destructive and sudden, usually causes serious casualties and also easily leads to landslides, mudslides, ground cracks and other secondary disasters.

Domestic and foreign scholars have been concerning about the prediction and assessment of earthquake risk and have made big progress[1] . Nie[2] obtained the risk formula based on the risk characteristics of the earthquake disaster, and got the risk result of china during a certain time scale. Chen [3] used GDP and population data to establish the damage assessment model of earthquake disaster and verified this model by some case. Liu [4-5] improved earthquake vulnerability model, then established macro earthquake risk model and got good results after verifying.

Experts and scholars mentioned above achieved a lot in the prediction and assessment of earthquake disaster risk, but what they focused on is relative and qualitative risk prediction and assessment, not its quantitatively analyzed. The paper established a simple disaster risk model, used the spatial analyst

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function of ArcMap system, and estimated the risk value of population in earthquake disaster quantitatively, finally, divided population high risk areas in Wenchuan earthquake region.

2. Estimation of population risk and division of risk area

2.1 Estimation of Population Risk in Earthquake Disaster

Earthquake has big threat to human life and property, when evaluates a earthquake disaster, the casualties accounted for a large proportion of total. The study of earthquake disaster population risk involved the natural and socio-economic systems in many aspects: 1) Disastrous factors. Mainly refers to the earthquake magnitude, intensity, and focal depth.2) Disaster-pregnant environment. It mainly includes earthquake region's population density, terrain topography and structure of the building, for example, the ability of concrete buildings' to resist earthquake is much stronger than wooden's.3) Disaster-affected bodies. It can be divided into two different categories: a) Male and female. b) Infant, child, the young, middle-aged, the old. Under the same disastrous factors and disaster-pregnant environment, middle-aged males' ability to resist earthquake are stronger than females'.

2.2 Division of Population Risk Area in Earthquake Disaster

Estimation of population risk in earthquake disaster, primarily to determine its relative value with a common method of risk areas' division, what needs key to point out is, each area we divided in the paper had the only value, they were qualitative based on quantitative value.

Areas' division of population risk in earthquake disaster refers to accord with research region's earthquake hazard value, then get the risk value by the superposition of population exposure (indicated by the letter E in the paper)in a certain scale, at last, group these regions into different risk levels according to their different risk values.

3. Population risk model in earthquake disaster

3.1 Population Risk Factor

The formation and development of earthquake disaster are influenced by a variety of natural and socio-economic factors. Combining with massive earthquake disaster mechanism information, it can be summarized than there are three factors which could influence the estimation of population risk.

1) Population exposure (E)

a) Definition of total disaster-affected bodies in risk assessment regions, for the financial material property, it can be instead of money; for the population, the unit is one person.

b) Estimation of population risk refers to predict how much people will probably die in a earthquake disaster. Within a certain period of time the exposure can be used instead of the current population exposure.

2) Coefficient of population damage (Q)

a) Percentage of population damage, namely, the death rate, $Q \leq 1$.

b) It could be determined by the following main factors: disastrous factors, disaster-pregnant environment, disaster-affected bodies.The coefficient can be got from approximate statistical data of the past disaster (supposed some position's disaster damage coefficient is invariable), or simulated it as a function curve.

3) The possibility of earthquake disaster occurrence (P)

a) The frequency of future disasters occurrence, of the volume, the units is, times / year.

b) It is also can be instead by historical events' statistical data, or built a related model. For the high degree of repetition of disaster, such as meteorological disasters, floods, historical events' frequencies can be used directly.

3.2 Risk Model

3.2.1 Overall Model

Through the risk factor's choice, it could be known that risk model belongs to one kind of quantitative model.

$$R = f(E, Q, P)$$

In the above equation, right side of the equal sign includes the factors' value which obtains through the different computational method. Each factor's relationship is nonlinear. Considered spatial distribution characteristics of the risk factors, integrated three kinds of factors into the space frame, then can obtain the risk value by synthesized each influenced factors. In the analysis calculation, the frame of grid can be used as the space framework, after completing the risk map, analyzing each grid of pixel, thus may obtain population risk value of unit area.

3.2.2 Process of Risk Model Establishment

Before the establishment of disaster risk model, various factors must be analyzed, firstly, proposed the definition of population hazard that refers to the proportion of population damage based on the same unit population exposure, or without considering the population exposure, population hazard can be expressed as the following formula:

$$H = Q \times P$$

H: population hazard; Q: coefficient of population damage; P: the possibility of earthquake disaster occurrence.

The population risk of earthquake disaster is the reflection of population hazard based on different population exposure, which can be summarized as the following formula:

$$R = E \times H = E \times Q \times P$$

R: population risk; H: population hazard; Q: coefficient of population damage; P: the possibility of earthquake disaster occurrence.

4. Analysis of population risk in wenchuan earthquake region

4.1 Introduction of Study Area

"5.12"Wenchuan earthquake affected nearly all over the china, mainly had several provinces as following: Sichuan, Chongqing, south Gansu, south Shannxi, south Ningxia, north Guizhou as well as north Yunnan. The paper's study region may include the above several parts.

4.2 Data of Risk Factors

1) Population Exposure (E)

As already pointed out above that the analysis calculation of risk used form of gird as the space framework, then used function of raster calculation of ArcMap, therefore, the data of population exposure of the paper used 1km national population distribution map of grid which was produced by Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, based on data of 2003 national population.

2) Coefficient of Population Damage (Q)

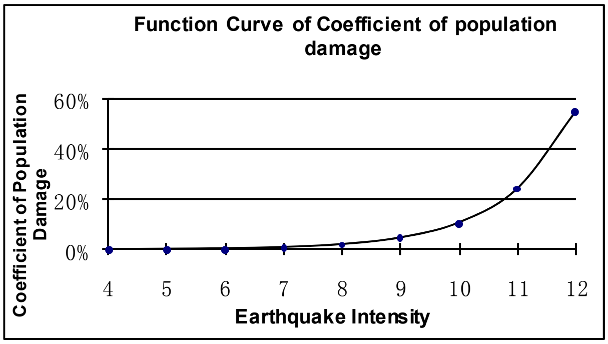
Indicators to Character the strength of earthquake activity include magnitude, intensity, peak ground acceleration. The basis earthquake data of this research mainly comes from "China Earthquake Data Center", 《Earthquake Cases in China (1966-1999)[6]; 《A Comprehensive Compilation of Historic and Recent Earthquakes Disaster Status in China》, which written by Lou[7];Recently years' review of the earthquake disasters. After collecting and analyzing the data of china's earthquake disaster between 1966 to 2010, using the "Pearson's correlation coefficient"statistics method, it is showed that earthquake intensity had a good correlation with disaster-affected bodies.

Table 1. Correlation Between Strength Endicators of Earthquake and Disaster-affected Bodies

Pearson coefficient	Death of the population	Injured population	Direct economic losses	Collapsed building
Magnitude	0.280	0.262	0.236	0.322
Intensity	0.409	0.392	0.441	0.468

Coefficient of population damage was obtained from 250 earthquake disaster cases from 1966 to 2010, then simulated the function curve shown in Figure 1, which based on the death population and the distribution of earthquake intensity zones in a case.

$$y = 3\times10^{-5} e^{0.8185x}$$



Function Curve of Coefficient of Population Damage

Verified accuracy of the curve: According to data released by Ministry of Civil Affairs and the State Seismological Bureau ,in the 2008 Wenchuan earthquake, the number of deaths in Wenchuan county is 23871 people (included the 7930 missing people)and the center intensity of earthquake was 11 degree, while in 2008, the total population in Wenchuan county before the disaster is 106119, after calculating, the dead people should be 25887, the error rate was 8.4%, actually,there were 10 degree, 9 degree intensity zones in Wenchuan county, the theoretical value should be less than 25887, so the population damage curve is more accurate and available.

3) The Possibility of Earthquake Disaster Occurrence (P)

The study area was Wenchuan earthquake region, which mainly involved seven provinces, autonomous regions and municipalities (already indicated above). Taking the provincial administrative regions as the study objects, according to the epicenter distribution of the earthquake disaster events between 1966 to 2010, then calculating the possibility of earthquake disaster occurrence in each provincial administrative region under different intensity.

4.3 Map Anaylsis

Identification of population risk, function of raster calculation of ArcMap was used in the paper, then overlaid various factors, got the population risk distribution map finally. Actually, it can be divided into two steps, firstly, considered coefficient of population damage and the possibility of earthquake disaster occurrence ,the distribution map of population hazard could be obtained; then made the population exposure overlay the hazard map, population risk distribution map was finally got.

1) Analysis of Population Hazard

As mentioned earlier, different intensity has a coefficient of population damage, so some treatment should be done to get the population hazard:

$$H = \sum_{i=4}^{12} Q \bullet P$$

By the calculation, distribution map of population hazard was obtained with the classification of hazard based on the provincial administrative regions, the map was shown in Figure 3.

As shown in the map, the population hazard was divided into five levels (shown in Figure 2)based on the units of provincial administrative, namely, lower hazard area, low hazard area, middle hazard area, high hazard area and higher hazard area. There were something should be explained: a) Classification of 5 levels was based on range of hazard value with considering the distribution of china earthquake zone, fault zone and the epicenter distribution of historical earthquakes, actually, the hazard value of each province was different. b) The hazard value of Guizhou province is 0 after calculating, which did not mean that earthquake disaster would never happen in Guizhou province or the population in Guizhou province would not be infringed by earthquake, but in the time scale of statistics between 1966 to 2010, there was no earthquake disaster in Guizhou, whereas, in history, there were earthquake disaster's records, so Guizhou province was treated as the lower hazard area.

$$\text{Hazard Level} \begin{cases} \text{Lower Hazard} & H = 0 \\ \text{Low Hazard} & 0 < H < 0.0005 \\ \text{Middle Hazard} & 0.0005 \leqslant H < 0.001 \\ \text{High Hazard} & 0.001 \leqslant H < 0.01 \\ \text{Higher Hazard} & 0.01 \leqslant H \end{cases}$$

Figure 2 The Principle of Population Hazard Classification

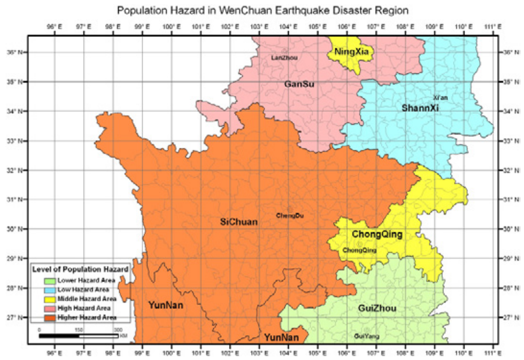


Figure 3. Distribution Map of Population Hazard in WenChuan Earthquake Disaster Region

2) Analysis of Population risk

Calculation of population risk can be expressed as formula (3). Selected 1km national population distribution map of grid and 1km national population hazard distribution map of grid as two factors of population risk, obtained the distribution map of population risk (Figure 4).

After inquiring, the following information can be achieved: this figure included 1111095 effective pixels, there is one pixel with maximum value of 627, the the minimum value is zero with a total of 890856 pixels. The size of each pixel is one square km, so maximum value of population risk is 627 people in unit area (1 sq km).

Through this distribution map, it could be known clearly that the population high risk areas are mainly distributed in eastern of Sichuan province, northern of Yunnan province, and there are small pieces of distribution in central and southern of Gansu province. At the same time there is no difficult to find the following rules: a) High risk areas are places where earthquakes happen frequently, which agrees well with the distribution of china earthquake zones. b) High risk areas have the densest population, that is, there would be large population damage while the same intensity of earthquake happen.

4.4 Analysis of Population Risk in A Small Regional Scale

In order to illustrate more clearly, taking Chengdu region

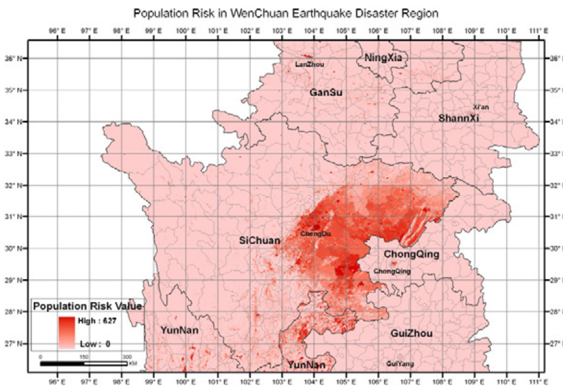


Figure 4. Distribution Map of Population Risk in WenChuan Earthquake Disaster Region

as an example by narrowing regional scale (Figure 5). This area includes Chengdu city, Shuangliu coutry, Jintang coutry, Jianyang coutry with an area of about 5824 square kilometers (numbers of effective pixels). After inquiring, there are a total of 173 different values, the maximum value is 207and the minimum is 0 with the number of pixels 78 (green area in Figure 5) and 56 respectively. Parts of risk values are selected to explain by a statistical chart (Figure 6).

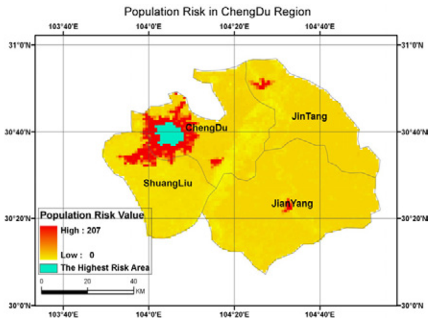


Figure 5. Population Risk in ChengDu Region

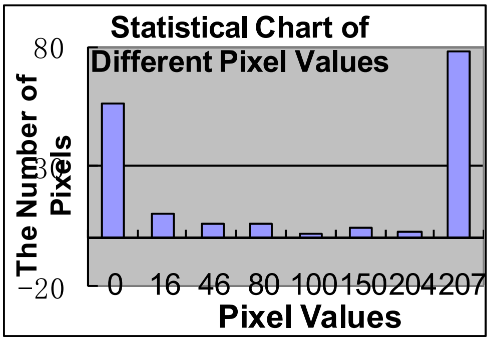


Figure 6. Statistical Chart of Different Pixel Values

5. Conclusion

1) The formation of earthquake is complicated which influenced by many factors, the model in the paper can also be used for analysis of other disaster-affected bodies.

2) The model built in this paper is a quantitative model, which can combine geographic information systems very well, such as the function of raster calculation used in the paper.

3)Through the inquiry function of population risk, specific region’s population risk value could be got, then necessary measures can be adopt to improve resistance ability of earthquake .

4) The classification of population risk zones can help governments to know the levels of risk of their regions, specifically to improve the capabilities of macro management so as to reduce the earthquake losses to a minimum.

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